1- A 7.5 cm O.D refrigerant pipe is exposed to an environment in which the heat transfer coefficient is 15 W/m^2.K. What thickness of cork insulation must be applied to reduce heat transfer to 20%, thermal conductivity of cork is 0.03 W/m.K. If the heat transfer coefficient of air is 6 W/m^2.K and thermal conductivity of an insulation material used is 0.1 W/m.K will the insulation be effective on a 3 cm O.D pipe.

2- Drive an expression for the general equation of heat conduction in spherical coordinates.

① Data: $OD = 7.5\ cm$ Req:- Thickness of insulation

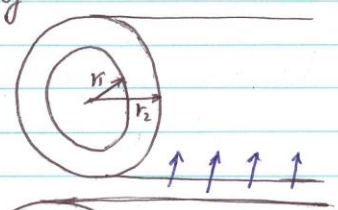
$h_o = 15\ W/m^2.K$

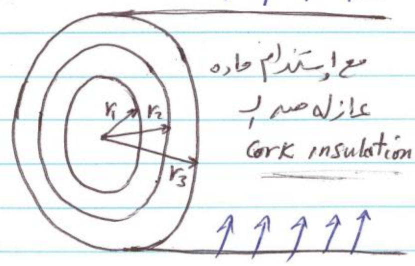
$Q_2 = 0.2\ Q_1$

$K_{cork} = 0.03\ W/m.K$

$h = 6\ W/m^2.K$

بدون مادة عازلة





مع إستخدام مادة
عازلة صمغ
Cork insulation

soln

without insulation

$$Q_1 = \frac{\Delta T}{\frac{1}{h_o \cdot 2\pi r_2 L}}$$

with insulation

$$Q_2 = \frac{\Delta T}{\frac{\ln r_3/r_2}{2\pi K_{cor} L} + \frac{1}{h_o \cdot 2\pi r_3 L}}$$

But $Q_2 = 0.2\ Q_1$

$$\frac{\cancel{\Delta T}}{\frac{\ln r_3/r_2}{2\pi K_{cor} \cancel{L}} + \frac{1}{h_o \cdot 2\pi r_3 \cancel{L}}} = 0.2 \frac{\cancel{\Delta T}}{\frac{1}{h_o \cdot 2\pi r_2 \cancel{L}}}$$

$$\frac{\ln r_3/0.0375}{2\pi * 0.03} + \frac{1}{2\pi * 15 * r_3} = 1.41471$$

let $r_3 = 5\ cm \Rightarrow LHS = 1.7384$ } by interpolation
let $r_3 = 4.5 cm \Rightarrow LHS = 1.203$ }

$$\frac{r_3 - 5}{4.5 - 5} = \frac{1.4147 - 1.7384}{1.203 - 1.7384} \Rightarrow r_3 = 4.6977\ cm$$

$$\underline{\delta}_{ins} = 0.9477\ cm \simeq 1 cm$$

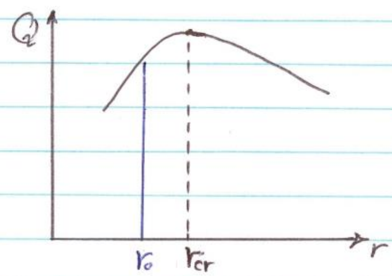
* For $h_o = 6\ W/m^2.°C$ and $K_{ins} = 0.1\ W/m.°C$ and $OD = 3cm$ ⇒ will the insulation be effective

For $r_{cr)cy} = \frac{K_{ins}}{h_o} = \frac{0.1}{6} = 0.0167\ m = 1.67\ cm$

$r_o = 1.5\ cm$

⇒ $r_o < r_{cr}$ ⇒ The insulation not effective

لأنه سوف يؤدي إلى زيادة Q



3- A 5 mm thick 10 cm long aluminum fin (k= 200 W/m.K) protrudes from a wall at 300 °C. Ambient temperature is 50 °C. The heat transfer coefficient between the fin surface and air is 10 W/m^2.K. Calculate the heat loss from the fin per unit depth of material. Also calculate the efficiency and effectiveness of the fin.

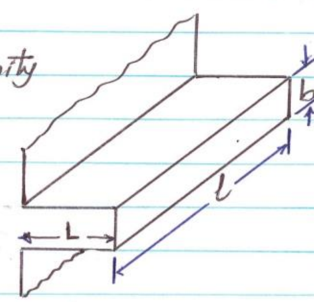
2- Drive an expression for the critical radius of insulation for cylindrical layer.

Data: $b = 5\ mm$ $K = 200\ W/m.K$

$L = 10\ cm$ $T_o = 300°C$ $\ell = $ unity

$T_\infty = 50°C$ $h = 10\ W/m^2.K$

Req:- ⓐ Q ⓑ η_f ⓒ ε_f



Soln

For short fin (general case)

$$Q_{fin} = \sqrt{hPKA_c} \cdot \theta_o \cdot \frac{\sinh mL + \frac{h}{mK}\cosh mL}{\cosh mL + \frac{h}{mK}\sinh mL}$$

$\because$ $m = \sqrt{\frac{hP}{KA_c}}$ and $P = 2(b+\ell)$ and $A_c = b \times \ell$

$\theta_o = T_o - T_\infty$

$Q_{without} = h\,(b\ell)\,\theta_o$

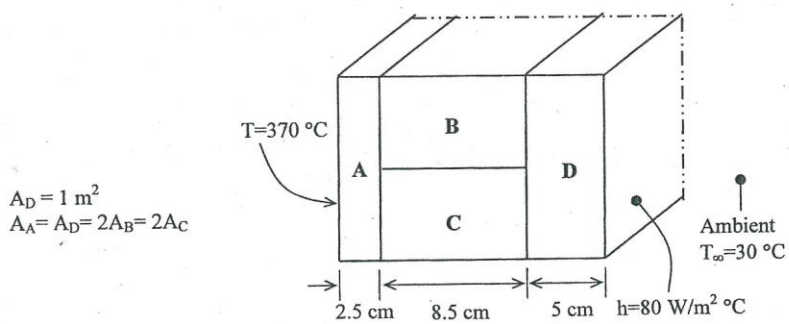
$Q_{max} = h\,(b\ell + 2bL + 2L\ell)\,\theta_o$

$\eta_{fin} = \frac{Q_{fin}}{Q_{max}}$ and $\varepsilon_{fin} = \frac{Q_{fin}}{Q_{without}}$

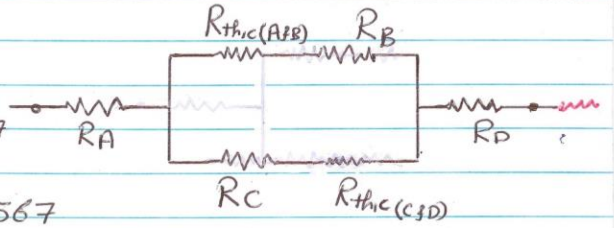
Question No. 1:

a) Define the following: thermal conductivity of a material, thermal contact resistance, and critical radius of insulation of a cylinder.

b) A composite wall is constructed as schematically shown in the figure. The thermal conductivities of the used materials are: k_A = 150 W/m°C, k_B = 30 W/m°C, k_C = 70 W/m°C, and k_D = 50 W/m°C. The thermal contact coefficient "h_c" in the interface between the parts A and B is 800 W/m^2 °C and between the parts C and D is 1000 W/m^2 °C. On the other hand perfect contact is considered between parts A and C and also between B and D. If the heat flow through the wall is assumed to be one-dimensional, determine the rate of heat transfer per unit area of the wall. Also, determine the outer temperature of the wall.



Given :- Composite plane wall



$$R_A = \frac{L_A}{K_A \cdot A_A} = \frac{0.025}{150 * 1} = 0.000167$$

$$R_B = \frac{L_B}{K_B \cdot A_B} = \frac{0.085}{30 * 0.5} = 0.00567$$

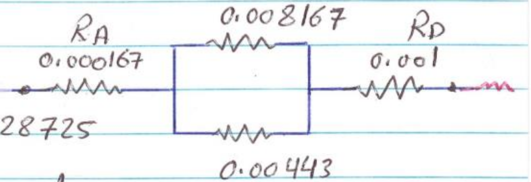
$$R_C = \frac{L_C}{K_C \cdot A_C} = \frac{0.085}{70 * 0.5} = 0.0024286$$

& $R_{th,c(A\&B)} = \dfrac{1}{h_c * A_B} = 0.0025$ (h_c = 800, A_B = 0.5)

$$R_D = \frac{L_D}{K_D \cdot A_D} = \frac{0.05}{50 * 1} = 0.001$$

& $R_{th,c(C\&D)} = \dfrac{1}{h_c * A_C} = 0.002$ (h_c = 1000, A_C = 0.5)

$$\Sigma R_{th} = R_A + R_{eqn} + R_D$$



$$R_{eqn} = \frac{0.008167 * 0.00443}{0.008167 + 0.00443} = 0.0028725$$

$$\Sigma R_{th} = 0.00404$$

$$R_{conv} = \frac{1}{h * A_D} = 0.0125 \quad (h = 80)$$

$$Q = \frac{\Delta T}{\Sigma R_{th} + R_{conv}} = \frac{370 - 30}{0.01654} = 20556.85 \text{ Watt}$$